6.2 1. GOING THROUGH THE AVAILABLE PLOTS IN TBROWSER
LOOKING UP VARIABLE NAMES IN THE DOCUMENTATION
FOR INTERESTING/UNIQUE PLOTS

2. THE vxp_z VARIABLE DEPICTS THE Z-POSITION
OF THE PRIMARY VERTEX

THE NUMBER OF ENTRIES 7 917 590 IS THE NUMBER
OF COLLISIONS OBSERVED.
THE MEAN GIVES THE ~~AVER~~ MEAN POSITION OF THESE
COLLISIONS, WHICH IS NOT QUITE CENTERED IN THE
DETECTOR, BUT RATHER A BIT BIASED TO THE LEFT
BY −9,163 PRESUMETLY mm.

3. OF THE TWO BEAMS IN THE LHC. EACH HAS
3564 BUNCHES OF WHICH 2808 CAN BE
FILLED WITH PROTONS.
EVERY BUNCH SLOT CONTAINS $N = \mathcal{O}(10^{11})$ PROTONS
SLOTS ARE SPACED BY 25 ns

VARIATIONS IN SPACING BETWEEN & WITHIN BUNCHES WILL
DIRECTLY AFFECT WHERE IN THE DETECTOR THE
COLLISIONS OCCUR.

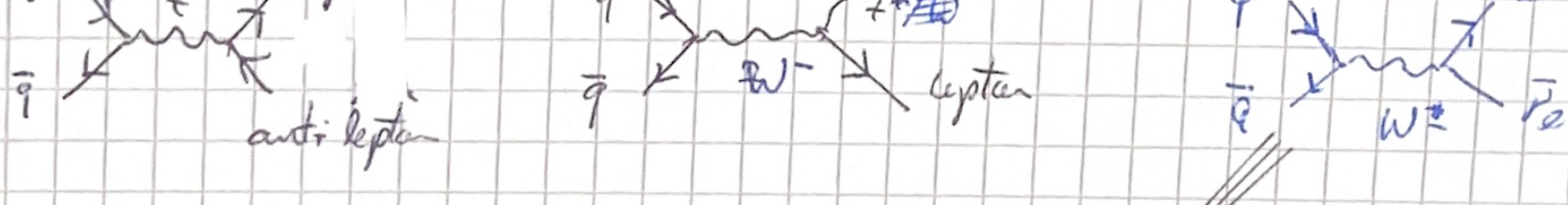
A MISSMATCH IN BUNCH SIZE COULD LEAD TO INTERACTIONS
AT DIFFERENT LOCATIONS WHICH WOULD SHOW UP
AS DISTINCT SEPERATE PEAKS

CONSIDERING THE CURRENT BINNING THERE SEEMS
TO BE ONLY ONE PEAK.
SMALLER DEVIATIONS COULD BE OBSERVED WHEN
COMPARING TO GENERATED DATA USING THE
MEAN & STD DEVIATION

whole transition from
Calorimeter to ___
and we lose leptons there

4. lep_n DEPICTS THE NUMBER OF PRESELECTED LEPTONS,
I.E. NUMBER OF LEPTONS PRODUCED SINCE DATA IS
PREFILTERED.
THE PEAK IN THE 1. BIN SUGGESTS THAT MOST INTERACTIONS
YIELD A SINGLE LEPTON WITH A DRASTIC DECREASE
IN MULTILEPTON PRODUCTION.
MORE THAN 3 LEPTONS & 0 LEPTONS ARE NOT OBVIOUSLY
DEPICTED IN THE PLOT.

5. Initially we expected 2 lepton in the final state, since it correspond to the tree-level
Feynman diagram. In this case, due to the high energy, $\sqrt{s}$, more complex diagrams
play a role and we get more, or less, than 2-leptons.



6.2 $\boxed{6}$ LEP_PT VARIABLE DESCRIBING THE TRANSVERSE MOMENTUM.
THE RISE AROUND 25GeV IS A RESULT OF THE DATA PRESELECTION, SO THAT ~~FEW~~ LEPTONS UNDER THAT ENERGY ARE OBSERVED.
WE OBSERVE A SOMEWHAT EXPONENTIAL DROP IN COUNT AT HIGHER TRANSVERSE MOMENTA.
THE MEAN LEP_{PT} FALLS AROUND ~~50 GeV~~ 30 GeV.

AT LEAST ONE HAS TO BE ABOVE 25GeV
THE FEW BELOW 25GeV ARE MEASURED IN MULTILEPTON PRODUCTIONS

THE LEP_ETA VARIABLE CONTAINS THE PSEUDO RAPIDITY
DUE TO THE DETECTOR SETUP THERE ARE NO MEASUREMENTS PAST $\eta \sim 2{,}5$ WHICH IS THE CUTOFF TO THE LEFT & RIGHT.
THE CAUSE OF THE GAPS BETWEEN $\pm 1{,}4 - \pm 1{,}5$ ARE THE

THE LEP_~~ETA~~ PHI VARIABLE DEPICTS THE AZIMUTHAL ANGLE OF THE LEPTONS.
DUE TO THE UNIFORMAL ACCEPTANCE OF THE DETECTOR WE OBSERVE A FAIRLY FLAT DISTRIBUTION.
THUS WE OBSERVE VALUES EVENLY BETWEEN $\pm\pi$ RAD

THE NUMBER OF ENTRIES DESCRIBE ALL THE MEASURED LEPTONS. DUE TO THE PRESENCE OF SOME COLLISIONS WHERE MULTIPLE LEPTONS ARE PRODUCED WE FIND THAT THE TOTAL NUMBER OF ENTRIES IS HIGHER THAN IN 2.

6.3 $\boxed{7}$ WHAT THE SCRIPT DOES
- IMPORT NECESSARY PACKAGES
- EXAMINE COMMAND LINE ARGUMENTS PROVIDED IE. INPUT FILE & NUMBER OF EVENTS
- CHECK VALIDITY OF INPUT FILE & OPEN IT
- ACCES THE TREE CONTAINING THE VARIABLES
- CREATES AN OUTPUT FILE
- INITIALIZE A HISTOGRAM
- LOOPING OVER DATA FILLING THE HISTOGRAM & UPDATING PROGRESS OUTPUT
  - HANDLING DATA THAT IS STORED IN VECTORS
- CREATING A CANVAS TO DRAW THE HISTOGRAM
- WRITING TO OUTPUT FILE

WE LIMIT THE NUMBER OF EVENTS TO 50 000.

WHEN RUNNING THE SCRIPT WE GET A HISTOGRAM OF THE VXP_Z VARIABLE. DUE TO THE LIMITED NUMBER OF ENTRIES OBSERVED & THE ~~VARYING~~ DIFFERENCE IN BINNING WE OBSERVE DIFFERENT VALUES FOR THE MEAN & STD DEVIATION.

WE TRY PRINTING OUT SOME OF THE VARIABLES IN THE TREE
BOTH VXP_Z & LEP_N ENTRIES ARE NUMERIC, BEING FLOATS FOR THE INTERACTION VERTEX, AND INTEGERS FOR THE NUMBER OF LEPTONS PRODUCED.
THE OUTPUT OF LEP_PT IS GIVEN BY A LIST, WHERE THE NUMBER OF ENTRIES CORRESPOND TO THE NUMBER OF LEPTONS PRODUCED IN THAT COLLISIONS. THE FLOAT VALUES CONTAINED BEING TRANSVERSE MOMENTUM

THE CONVERSION FROM MEV TO GeV CAN BE DONE IN THE PRINTOUT ' print ('lpx_pt:', [pt/10000 for pt in myCHAIN.lep_pt])

-RYING TO PRINT OUT LPX_ETA WE GET POINTERS TO THE SAME LOCATION FOR ALL VALUES SEEMINGLY

[3] - we use the definition of θ from spherical coordinates $\cot\theta = \frac{p_z}{p_T}$

we now insert def. of y in $\sinh(y)$: $\sinh(y) = \left(e^{-\ln(\tan\theta/2)} \quad e^{\ln(\tan(\frac{\theta}{2}))}\right)\frac{1}{2}$

$\Leftrightarrow \frac{1}{2}\left(\cot\frac{\theta}{2} - \tan\frac{\theta}{2}\right) = \frac{1}{2}\,\frac{\cos^2(\theta/2) - \sin^2\theta/2}{\cos\theta/2 \cdot \sin\theta/2}$ → now we use trig. identities

$= \frac{\cos\theta}{\sin\theta} = \cot\theta \Rightarrow \sinh y = \cot\theta = \frac{p_z}{p_T} \Rightarrow p_z = p_T \sinh(y)$

WHEN IMPLEMENTING THIS, WE ITTERATE THROUGH A NUMBER OF ENTRIES. WE LIMIT THE M^2_{ll} VALUES TO THOSE >0 BY ONLY ADDING THESE TO THE PLOT.

→ 30GeV max is effe of p_T-cut.

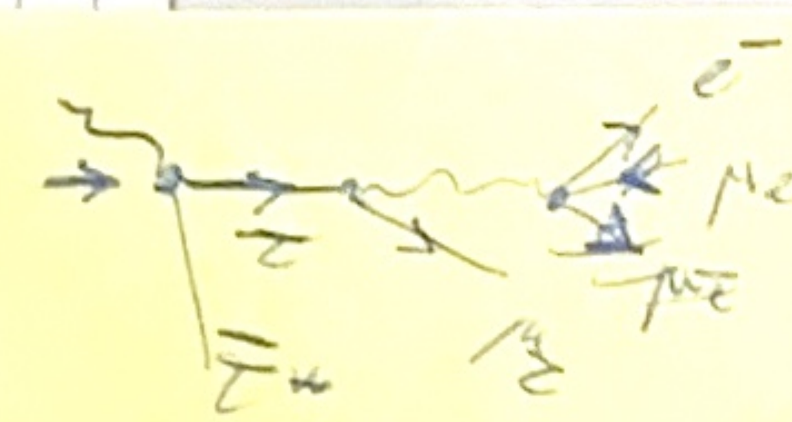
10GeV Y - Botten resonance
5GeV J' - charm resonance
$q\bar{q}$ likely decay into leptons

EXAMINING THE PLOT WE OBSERVE A MAJOR PEAK AROUND 90 GeV WITH A ROUGHLY GAUSSIAN SHAPE TOWARDS THE RIGHT, WITH FEW TO NONE MAJOR MASSES MEASURED BEYOND. ~~BUT THE~~ BUT THE MEAN VALUE OF THE HIST IS AT 73,74 GEV WITH A STD DEV OF 29.65. THIS IS DUE TO A NUMBER OF ENTRIES & SMALLER PEAKS ~~BELOW~~ BELOW THE 90GeV PEAK. MOST OF THESE ENTRIES AROUND 30GeV & 6 GeV WITH A STEADY BASELINE OF ~ 220 ENTRIES.

Since for now, we haven't add strong constrains to the events used, we suspect, that the peaks with $\sqrt{s}$ < 30 GeV are results from leptons produced by other decays/processes and not directly by Z-Boson decays.

~~COMPARING~~ + NOW EXAMINING THE MONTE CARLO PLOT WE ARE NOT OBSERVING ~~RE~~ THE PREVIOUS PEAKS BELOW THE EXPECTED VALUE & THE MAIN PEAK IS HIGHER IN AMPLITUDE.

From the log & log-log scale, we don't get much more information, we rather get a better comparison of the peaks with $\sqrt{s}$ < 30 GeV. Where we see that the ~~bot~~ low $\sqrt{s}$ entries reach ~200 in measurement, while ~~#~~ in MC they barely go over 10.



we only see the leptons which come from the Tau decay. They are instable and decay before they get detected. We can study it identify them from the p_T of ν_e & ν_τ

6.4 [1] THE MOST INFLUENCIAL CUTS IN THE HISTOGRAM SEEM TO BE THE PRIMARY VERTEX & THE OPPOSITE CHARGE CUT.

[2] Event-Level cut are more general constraints which are not Z-Boson specific, such that particles not coming from the desired decay pass-through. Whereas more specific conditions, which are specifically tailored for the decay tend to play a more important role, e.g charge neutrality.

6.3 [4] WE CALCULATE THE INVARIANT MASS USING TLORENTZVECTOR BY INITIALIZING LEP1 & LEP2 VECTORS, APPLYING .SET PtEta Phi M WITH THE VALUES AND PASSING VALUES FROM THE TREE. LASTLY APPLYING THE .M METHOD TO THE SUM OF THE LEPTONS.

WE ADJUSTED THE LINE WIDTH OF THE MANUAL VALUES TO BE THICKER, SINCE THE HISTOGRAMS COVERED EACH OTHER IDENTICALLY, AS FAR AS WE CAN TELL.
CONSIDERING THE LINES NEEDED TLORENTZVECTOR IS EASIER TO USE & LESS PRONE TO USER ERROR.

[5] SINCE THE INVARIANT MASS OF THE BOSON IS CONSERVED

THE THE INVARIANT MASS OF THE OBSERVED LEPTONS SHOULD BE THE SAME. PREVIOUS OBSERVATIONS OF THE PLOTS HOLD TRUE.
WITH SOME SURPRISE WITH RESPECT TO THE HIGH NUMBER OF ENTRIES AT LOWER INV. MASSES
THE SMALLER PEAKS AROUND ~5GeV & ~30GeV.

6.4 [3] THE RESULTING HISTOGRAMS OF THE EGAMMA & MUON DATA NOW APROXIMATE A BELL CURVE MORE CLEANLY. THE HARD CUTOFF IMPLEMENTED AROUND 80-100 GeV IS SLIGHTLY NOTICABLE.
FOR THE EGAMM & MCZEE WE USE trigE, FOR MUON & Zmumu THE trigM IS USED. WE OMIT THIS TRIGGER FOR ZTAUTAU SINCE IT IS NOT THAT INFLUENCIAL & THERE IS NO trigT.

THE TAU MC SET SHOWS A PEAK AROUND 46GeV AND IS THUS ALMOST ENTIRELY CUT BY THE INVARIENT MASS TRIGGER

6.5 [1] WE COMBINE THE EGAMM & MUON DATA INTO ANALYSIS_MERGED AND USED THE TBROWSER TO QUICKLY VALIDATE THE INTEGRITY OF THE PLOT.
~~We then~~

[2] We proceed by finishing the code plot.py which allows us to plot the invariant mass distribution generated with the measurements and with the MC. Here we take into account the proper scaling for the simulations by multiplying them with
$\alpha = lum \cdot xsec\_i / sumw\_i$

6.6 [1] First we remind ourselves, that according to the central limit theorem ~~the~~ a statistical distribution converges to a gaussian distribution if the number of samples $n \to \infty$ while expectation value μ and variance σ remain finite. We see that ~~our~~ our data set fullfils said requirements, thus the Gauss distribution takes into account the statistical nature (random & binomial) of the experiment.

On the other hand, the Breit-Wigner distribution is related to the physical properties of the system. The former distribution describe the probability of finding a particle with a certain energy at a given ~~mass~~ cross section. In short it describes unstable particles, e.g Z-Boson, in vacuum

In conclusion by taking both the physical and statistical nature of the process is that we can get a satisfactory fit.

$\boxed{2}$

From PDG we read $M_{Z,PDG} = 91,188 \pm 0,0020$ GeV and $\Gamma_{Z,PDG} = 2,4955 \pm 0,0023$ GeV.

Whereas from our analysis fitting the convolution of a Breit-Wigner and a Gauss distribution we find/determine

$$M_Z = 90,629 \pm 0,005 \quad , \quad \Gamma_Z = 3,258 \pm 0,021.$$

We calculate the deviation from both values

$$\sigma_{M_Z} = \frac{|M_{Z,PDG} - M_Z|}{(\Delta M_{Z,PDG}^2 + \Delta M_Z^2)^{1/2}} = 27,11.$$ Analogously we find σ_{Γ_Z}.

$\sigma_{\Gamma_Z} = 36,09$. From this comparison we can clearly see that our values deviate significantly from the ones measured at the LHC.

⇒ e emit Brem-emission which makes the detection unclear
μ have a clearer peak due to the clearer path that they leave in our detector

ARBITRARITY OF THE ISOLATION CUT → TRY FOR DIFFERENT

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6.8|

Systematic errors:

→ fit model, it does not match the peak.

→ e missing energy due to Bremsstrahlung. Could correct for missing energy.

modify the Breit-Wigner add extra parameters to move the peak and model the asymmetry

6.~~7~~ ☑ WE IMPLEMENT THE TAG & PROBE METHOD FILTERING FOR TIGHT LEPTONS & RUNNING WITH ALL DATA
SAVING INTERMITTEN VALUES IN DENOMENATOR & NUMERATER, WHICH WILL ALLOW US LATER TO CALCULATE THE ERROR USING A BINOMIAL DISTRIBUTION SINCE A PARTICLE EITHER PASSES OR FAILS A TEST

$$E = \frac{\text{NUMERATOR}}{\text{DENOMINATOR}}$$

WITH THE EFFICIENCY

$$\sigma_E = \sqrt{\frac{E(1-E)}{\text{DENOMINATOR}}}$$

THIS CAN EASILY BE IMPLEMENTED USING THE OPTION B IN ROOTS TH1::DIVIDE

LIMIT OF 6 PAGES